Concrete Block and Riprap for Overtopping Protection

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The Bureau of Reclamation, in conjunction with EPRI (Electric Power Research Institute), and CSU (Colorado State University), has completed a four-year research study on concrete step overlay protection for embankment dams. Results show that stepped overlays are inherently stable due to the combined effect of the impact of the flow on the step surfaces and the ability of the stepped overlay to relieve the uplift pressure. Laboratory test results were used to design an individual block shape, to represent the stepped overlay, which has been successfully tested in a large outdoor facility at CSU in Fort Collins, CO.

The outdoor overtopping facility was sized to be similar in height to a typical embankment dam in need of rehabilitation. The facility consists of a concrete chute on a 2:1 slope with a height of 50 ft and a width of 5 ft. The discharge capacity is 31.6 $ft^3/s/ft$. The overlapping tapered concrete blocks, with a maximum thickness of 0.375 ft, were placed over free-draining, angular, gravel filter material. The filter material and thickness was designed according to Reclamation design guidelines. A combination of 2-ft and 1-ft-wide blocks were placed on the “embankment” shingle-fashion from the slope toe leaving no continuous seams in the flow direction. Drains, which aspirate water from the filter layer, are formed in the overlapped portion of the block.

Tests of the block system were completed in the near-prototype size outdoor facility in the fall of 1993. The block system remained stable and performed satisfactorily, even after some blocks were intentionally damaged. General design criteria have been developed dealing with the crest treatment, block size, energy dissipation and flow depths on the slope, and required toe treatment based upon energy remaining at the toe of the dam. The block system has U.S. patent number 5,544,973 and is available for licensing.

Riprap is commonly used to prevent erosion of the downstream face of dams during rainfall events. Often, it is expected to be able to protect a dam during small overtopping events. It is generally an inexpensive method proposed to provide stability while rehabilitating dams expected to overtop. River restoration projects often use riprap drop structures to prevent degradation of the channel invert.

Large-scale testing by Reclamation and Colorado State University produced initial guidelines for designing stable riprap slopes subjected to overtopping. Additional test data from 1997 have been incorporated into this previous work allowing verification of initial design guidelines. Input from embankment dam designers has prompted investigation into simplification of the initial guidelines into a more “user-friendly” form. The errors introduced by assuming a generic coefficient of uniformity, D_{60}/D_{10}, to eliminate determinating three rock sizes, have been computed and use of a safety factor specified. This will produce less concern about obtaining the specified rock gradation during inspection of an existing or construction of a new riprap overlay.

Another important aspect of the design is establishing the use of the guidelines over the full range of riprap slopes. Overtopping flow on embankments with slopes less than or equal to 0.25 (4H:1V) covers the riprap. For slopes greater than 0.25, the overtopping flow must be contained within the layer of riprap for stability, although an insignificant amount of highly aerated water splashes and cascades over the top of the riprap. The design guidelines specify procedures to deal with both slope situations and application of a safety factor to provide the designer confidence to use the guidelines.

Editors' notes: Related handout materials by these authors made available during the Workshop included:
Frizell, K. H. 1997. "Protecting Embankment Dams with Concrete Stepped Overlays." Photocopied from Hydro Review (Sep. 1997), beginning on page 36.
Frizell, K. H., J. F. Ruff, and S. Mishra. 1997. "New Riprap Design Criteria to Prevent Embankment Dam Failure During Overtopping." *Proc. 1997 Annual Meeting,* Association of State Dam Safety Officials, Inc..
These materials are available by contacting the authors directly; see participant address section at end of this Proceedings.

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